A COMPARISON BETWEEN AGE DETERMINATIONS OF THE ANTARCTIC FISH *NOTOTHENIA GIBBERIFRONS* LÖNNBERG USING SCALES AND OTOLITHS

by

Roger COGGAN(1), Krzysztof SKORA(2), Alistair MURRAY(1)
and Martin WHITE(1)

ABSTRACT. - Scales and otoliths were collected from 304 specimens of the Antarctic fish *Notothenia gibberifrons*. When interpreted separately, only 25% of scale and otolith readings agreed. When a scale and otolith from a single specimen were interpreted simultaneously, 75% of readings agreed. 60% of scale readings and 30% of otolith readings changed between separate and simultaneous interpretations. Estimates of age tend to be lower when made from scales. Predictions of yield per recruit utilising age data derived from scales are approximately 30% greater than predictions utilising age data derived from otoliths.

RÉSUMÉ. - Des écailles et otolithes ont été prélevés sur 304 spécimens du poisson antarctique *Notothenia gibberifrons*. Lorsque les lectures d'âge à partir d'écailles et d'otolithes avaient été analysées séparément seulement 25% des résultats coincidaient. Lorsque une écaille et un otolithe du même spécimen avaient été analysés en même temps, 75% des lectures concordaient. 60% des lectures d'écailles et 30% pour les otolithes différaient selon que les interprétations avaient été séparées ou simultanées. Les estimations de l'âge ont tendance a être moins élevées lorsqu'elles sont fondées sur les écailles. Les prédictions de rendement par recrue utilisant les déterminations d'âge obtenues à partir des écailles sont approximativement 30% plus élevées que les prévisions utilisant les données de l'âge fondées sur les otolithes.

Key-words: Nototheniidae, *Notothenia gibberifrons*, PSW, South Georgia, Antarctica, Age determination, Otolith reading, Scale reading.

The study and management of fish populations require the acquisition of age data. The age of Antarctic fish is usually determined by studying growth increments in the hard tissues, most commonly scales and otoliths. Ideally, there should be no variation between repeated interpretations of one material or between the interpretation of different materials sampled from the same specimen. However, variations do occur due to the subjectivity of observations and the differential formation of the hard structures and marks within them (Hureau, 1970; Freytag, 1980).

The standardisation of methods of preparing materials and subsequent interpretation is therefore important and has been the subject of two workshops organised by the Fish Biology Working Party of the SCAR/SCOR/IABO/ACMRR Group of Specialists on Living Resources of the Southern Ocean (Everson, 1980; DeWitt, 1982), and one organised by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) in Moscow 1986 (Lubimova, in prep.).

---

(1) British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge, CB3 0ET, UNITED KINGDOM.
(2) University of Gdansk, Hel Marine Laboratory, 84-150 Hel, P.O.Box 27, POLAND.

Cybium 1990, 14(1): 43-55.

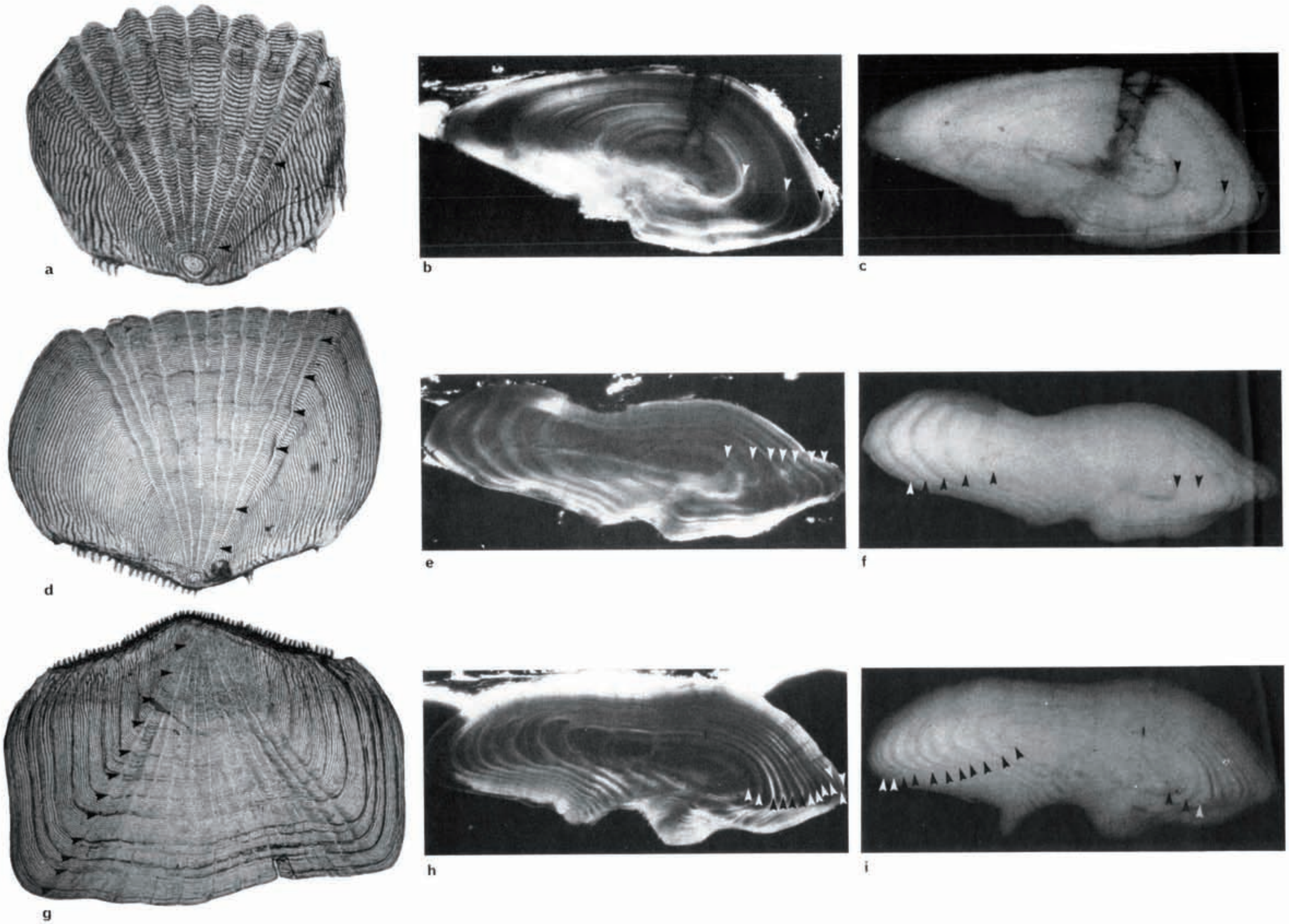

Fig. 1: Interpretation of age from scale and otolith material of three specimens of *Notothenia gibberifrons* caught in December 1986 (with annuli indicated). a, b, c: Age estimated as 3 years old, total length = 177mm. d, e, f: Age estimated as 7 years old, total length = 321mm. g, h, i: Age estimated as 13 years old, total length = 416mm.

It is important to resolve the confusion which still exists regarding which of the various published length-at-age schedules are most appropriate to the South Georgia stock of *N. gibberifrons* (Gabriel, 1987) in order that the exploitation of this stock can be properly managed. Specific requests have been made by CCAMLR for age-length keys for *N. gibberifrons* for recent years (Anonymous, 1988). As a contribution to this work we were interested in investigating differences between age estimates derived from scales and those derived from otoliths, and identifying which material produced the most reliable results.

Kock *et al.* (1985), from various published data, have estimated the status of the South Georgia stock of *N. gibberifrons*. They predicted the yield per recruit and used this to infer the effect of the fishery on the stock. However, the validity of any comparisons between published data must be suspect if the estimation of age is inconsistent. We examine how the difference between age estimates derived from scales and those derived from otoliths affects predictions of the yield from an exploited stock using currently applied management models. We highlight the limitations of such models and make recommendations regarding the suitability of certain ageing methods for use in future stock assessment.

The terminology used to describe techniques and the interpretation of growth increments is according to Everson (1980).

MATERIALS AND METHODS

Materials were collected in collaboration with scientists from the United States and Poland during Phase I of the U.S. Antarctic Marine Living Resources Program Ecosystem Monitoring Survey 1986-87, conducted aboard the R.V. Professor Siedlecki (Anonymous, 1987a). Scales and otoliths were collected from *N. gibberifrons* sampled from 37 stations on the South Georgia continental shelf during the summer season (between 30 November and 16 December 1986) with a Polish commercial bottom trawl (80mm stretched mesh, 20mm stretched mesh cod-end liner). Total length of specimens was measured to the nearest millimetre below.

Materials were stored dry. Scales, taken from the mid-lateral region posterior to the pectoral fin articulation, were washed in detergent, mounted between glass slides and dried. The slides were placed in a microfiche reader and the image of the scale analysed; only complete distinct annual checks were counted (Fig. 1 a,d,g).

Otolith sections (0.5mm) were prepared by the thin-sectioning technique (Bedford, 1983) and hyaline zones counted using a binocular microscope. Two forms of illumination were necessary as the innermost hyaline zones were more clearly visible using transmitted light (Fig. 1 b,e,h) whereas the outermost zones were best observed using reflected light (Fig. 1 c,f,i). Dark field illumination under transmitted light was achieved by the use of two polarising filters aligned 90° out of phase.

All samples of scales and otoliths were interpreted twice. On the first occasion they were read separately, a scale reader (Skora) interpreting the scales and a otolith reader (Coggan) interpreting the otoliths. On the second occasion they were read simultaneously. A video camera was attached to the microscope used to examine the otolith and the monitor for the camera placed next to the microfiche reader used to examine scales, allowing immediate comparison between the two samples from the same specimen. Working together, the readers then interpreted the scale and the otolith without reference to the initial interpretations. If there was some discrepancy between the scale and otolith readings in this simultaneous interpretation, the corresponding annuli in the two materials were matched to identify any evident misinterpretations (false checks or indistinct annuli). If misinterpretations were found then the results were adjusted accordingly. If no misinterpretation was found then the discrepancy was allowed to stand.

The complete data set has values for total length and four separate age interpretations for a total of 304 specimens. The four age estimations were denoted as follows.

Age from scales, separate interpretation ....Sc1.
Age from otoliths, separate interpretation ....Ot1.
Age from scales, simultaneous interpretation ....Sc2.
Age from otoliths, simultaneous interpretation ..Ot2.

Instances where Sc2 = Ot2 (n = 233) were referred to as the 'joint agreed age' and this subgroup denoted as SO.

Statistical analyses and the fitting of the Von Bertalanffy growth model were performed on a VAX 8350 computer using the statistical package GENSTAT, version 5 (Payne *et al.*, 1987).

RESULTS

Summary of data

Figure 2 shows the length-frequency distribution of the 304 specimens in the sample. Total lengths ranged from 110mm to 500mm. It is clear that cohort analysis of this data would be most difficult. Figure 3 gives the age-frequency distribution for the 233 specimens of the subgroup SO as we believe that this subgroup provides the most reliable estimates of age.

Comparison of age interpretations

A comparison between two age interpretations, e.g. Sc1 and Ot1, was made by subtracting the value of Ot1 from that of Sc1 for each of the 304 specimens and calculating the frequencies of the resultant differences. The results of four comparisons are shown in Figure 4.

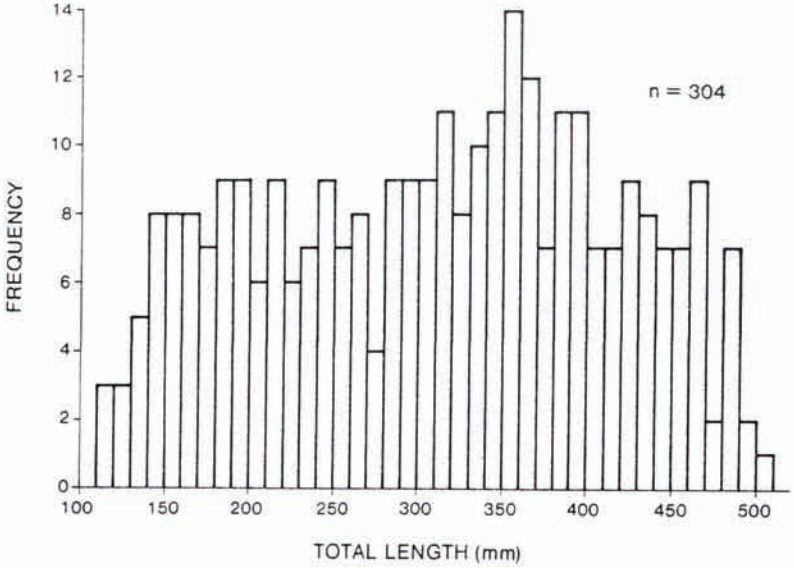

Fig. 2: Length-frequency distribution for the 304 *Notothenia gibberifrons* sampled for this study (with length in 10mm intervals, e.g. 100-109mm inclusive).

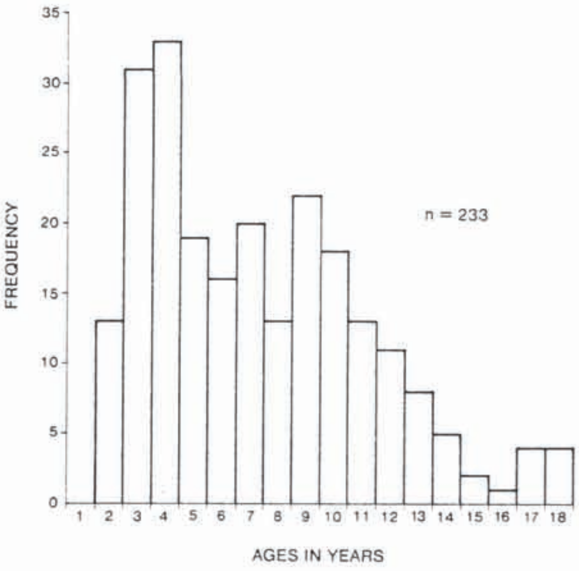

Fig. 3: Age-frequency distribution for the 233 specimens of *N. gibberifrons* belonging to the subgroup SO (see text).

Most variation is evident in comparisons involving Sc1 and it is clear from the asymmetry in Figures 4a and 4c that Sc1 generally gives lower estimates of age than Ot1 or Sc2. Figures 4c and 4d show that scales give a lower estimate of age than otoliths in both separate and simultaneous interpretations. A chi-squared (χ^2) test shows that the scale readings are significantly lower than the otolith readings ($p < 0.001$) for both interpretations, although the value of χ^2 for the simultaneous interpretation was less than that for the separate interpretation by a factor of ten.

Figures 4a and 4b show that the interpretation of otoliths is more consistent than that of scales. The least variation between any two interpretations is between Sc2 and Ot2 (Fig. 4d). There is a similar low variation between the two interpretations of otoliths (Fig. 4b).

Causes of variability between age determinations

It is important to account, as far as possible, for the observed variation between Sc1 and Ot1. The subjectivity of observations is always a likely source of error but this could not be investigated here as replicate readings of the same material by different observers were not made. Another possible cause of variation which could be explored was the differential formation of growth increments in scales and otoliths. Such differences could occur in the rate and/or onset of deposition of the growth increments.

The Von Bertalanffy growth formula (VBGF) is a widely applied mathematical model of fish growth. Lt, the length at age t (years), is calculated from the formula:-

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

where L_∞ (maximum theoretical length), k (instantaneous growth coefficient) and t_0 (theoretical age at which $L_t = 0$) are parameters to be estimated. The shape of the curve is determined by these three parameters where L_∞ fixes the asymptote of the curve, k defines the slope and t_0 is the intercept on the time axis.

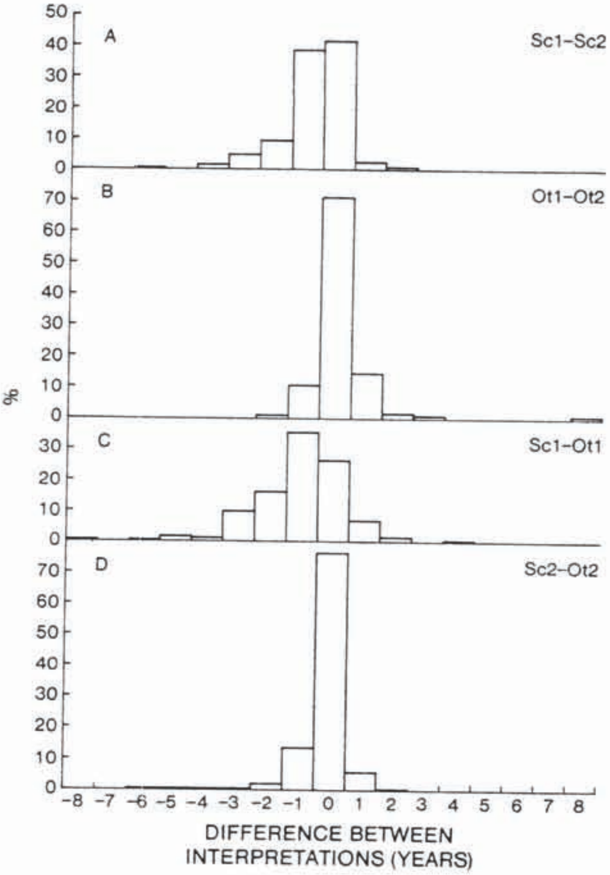

Fig. 4: Differences between various age interpretations of 304 specimens of *Notothenia gibberifrons* expressed as % frequency of the differences resulting from the following subtractions. a: Sc1 - Sc2. b: Ot1 - Ot2. c: Sc1 - Ot1. d: Sc2 - Ot2.

When this model was fitted to the data for the separate age interpretations, Sc1 and Ot1, different shaped curves were obtained (Fig. 5). These differences in shape can be due to differences in either L_∞, k or t_0 or any combination of these. The pattern of differences was investigated by comparing these curves with those produced when the model was constrained so that one, some or all of the parameters (L_∞, k or t_0) were common to the curves for Sc1 and Ot1. When compared to the fit of the unconstrained model, the goodness of fit of the various constrained models indicates which of the constrained models best explains the variation between the two age interpretations.

For these data, the model with common k and L_∞ and separate t_0 best explained the variation between Sc1 and Ot1. Thus the two curves of the constrained model (Fig. 6) have a similar shape, the curve for scales being shifted left along the time axis relative to that for otoliths.

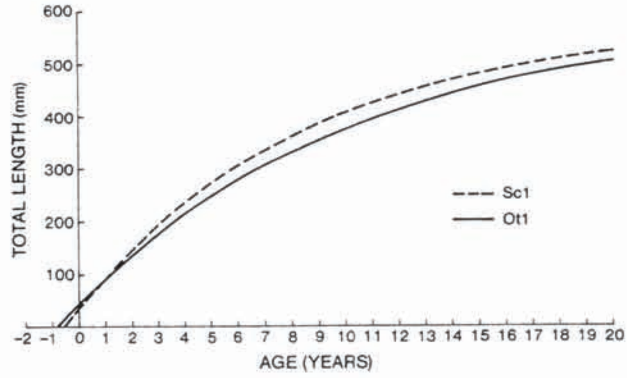

Fig. 5: Growth curves derived from fitting the unconstrained Von Bertalanffy growth model to the data for Scl (- - -) and Otl (—).

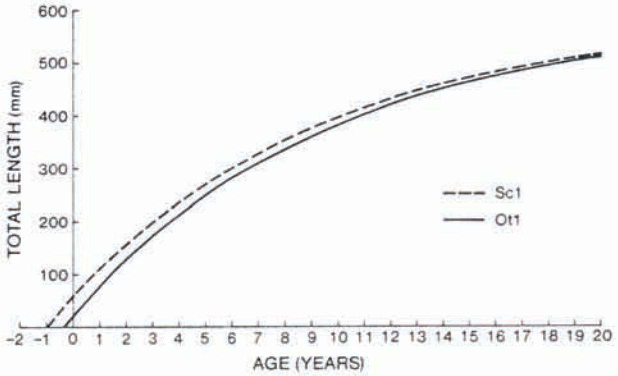

Fig. 6: Growth curves for Scl (- - -) and Otl (—) produced when the Von Bertalanffy growth model was constrained so that the curves had common values of L_∞ and k but different values for t_0.

DISCUSSION

Variability in age interpretations

Boronin and Frolkina (1976) found some discrepancy between their interpretations of scales and otoliths from fifty *N. gibberifrons* but deemed these to be insignificant and subsequently aged all of their specimens by the interpretation of scales alone. The results of our study show that for *N. gibberifrons*, the ages determined from scales are significantly different to those determined from otoliths. Age determination was most consistent when scales and otoliths were interpreted simultaneously (Fig. 4d) but the two interpretations of otoliths (Fig. 4b) gave a similarly low variability. A bias in the determination of age appears to arise in the interpretation of scales which tend to underestimate the age as derived from otoliths, usually by one year (Fig. 4c). In addition, the interpretation of scales is more variable than that of otoliths (Figs 4a, 4c). If a precise age is required then the interpretation of scales alone should be avoided.

The nature of the differences between Scl and Otl was investigated by fitting constrained models to the data. Since the length of the fish remains the same whether aged from otoliths or scales, it follows that L_∞ must be the same for both curves. If annuli were laid down at different rates in scales and otoliths then differences in the parameter k would wholly account for the differences in the curves when t_0 was forced to be the same for both. If, however, there were a difference in the onset of deposition of annuli in otoliths and scales but they were subsequently formed at the same rate, then the differences between the curves would be wholly attributable to different values of t_0 with the values for k and L_∞ common to both curves. Here, it was the latter model which best fitted the data and so we can conclude that growth increments were formed at the same rate in scales and otoliths. This conclusion is supported by the observations of North (1988).

The differences between Scl and Otl seem, therefore, to be reflected only in the parameter t_0. This parameter is commonly thought to represent a theoretical age at which the total length of the fish was zero, and relies on the assumption that the structures used to age the fish hold a complete record of growth throughout the fish's lifetime (i.e. they were first formed at time t_0). This underlying assumption is clearly incorrect as we have two different values of t_0 for the same sample of fish. In fact, the parameter t_0 has no simple meaning with respect to the life history of the fish; it is an abstract concept of value in modelling the data. Since we do not know the true age of the fish but merely the number of annual growth increments we have counted in the various hard structures, the two values we have obtained for t_0 indicate that scales and otoliths start to record the fish's growth at different times in its life history. We deduce that scales are formed later than otoliths because the Scl curve lies to the left of the Otl curve. However, it is not possible to determine, by extrapolation from this analysis, the magnitude of the time difference between the formation of scales and otoliths because the assumptions underlying the Von Bertalanffy model, such as constant growth rate, are not valid for larval growth or for growth periods less than one year.

The differential formation of otoliths and scales, and of the first annulus within them, has been observed in a number of Antarctic fish. For example, Hureau (1970) reports that for *Notothenia cyanobrancha*, otoliths have n opaque zones where scales have n-1 annuli. Freytag (1980) pointed out that the interpretation of the first annulus of scales from *Notothenia rossii* was open, as some fingerlings had fully formed scales (and presumably annuli) before their first winter but others still had no scales in March and would probably not form scales until after the following spring. Our study has deduced, from a mathematical model, that scales and otoliths do not form at the same time in *N. gibberifrons*. The model indicates that, on average, the difference is less than one year (t_0 for Scl = -0.534, t_0 for Otl = -0.812, difference = 0.278 years) which indicates that in some individuals the first annulus in scales and otoliths is formed synchronously, while in others the formation of the first scale annulus lags the formation of the first otolith annulus by one year.

We are not aware of any detailed studies of the formation of scales in *N. gibberifrons*. In a brief initial study, North (pers. comm.) has found that *N. gibberifrons* start to form scales at a total length of 37-40mm, a length attained in March by the 1977 cohort. Efremenko (1979) reported catching larval *N. gibberifrons* around South Georgia as early as November and as small as 8.5mm total length. Thus, the larvae observed by North could be up to five months old before scales begin to develop. Boronin and Frolkina (1976) found that annulus formation took place from April to October in immature individuals and between May and August in mature individuals. There is clearly a need for more study if the use of scales as a material for ageing *N. gibberifrons* is to be used with confidence.

Implications for stock assessment and management

A full assessment of the effect of the observed differences in age derived from scales and otoliths on stock assessment and management is beyond the scope of this paper. However, some implications of the effects of these differences can be illustrated by comparison of growth curves and yield per recruit (Y/R) curves based on the data from Sc1 and Ot1. Although the growth curves may look similar when plotted (Fig. 5), nevertheless small differences between them accumulate to give markedly different estimates of yield per recruit. Table I gives the estimates of parameters of the Von Bertalanffy growth curve fitted separately, that is with all parameters unconstrained, to the data for Sc1 and Ot1. These values are used in the calculations described below.

The estimations of yield per recruit (Y/R) presented in Figure 7 are based on the Beverton and Holt (1957) method of calculation, as simplified in tabular form by Gulland (1969). Following Kock *et al.* (1985), who performed a similar analysis on data based on ages determined from scales published by Boronin and Altman (1979), we have assumed values for the coefficient of natural mortality (M) = 0.3 and age at recruitment (t_r) = 3 years. Our values for W_∞ were derived from the length/weight relationship $W_\infty = 0.006L_\infty^{3.1787}$ proposed by Skora (1980) as this was centred in the range of length/weight relationships for *N. gibberifrons* quoted in table 4 of Kock *et al.* (1985).

The predictions of yield per recruit based on Sc1 (Fig. 7a) range from 20-30% greater (at a fishing mortality F = 0.5) than those based on Ot1 (Fig. 7b), a difference which could well affect a decision regarding the economic viability of a fishery directed at the South Georgia stock of *N. gibberifrons*. Knowing that age estimates based on the interpretation of scales are more variable than those based on the interpretation of otoliths it would be wise to err on the side of conservatism and use the Y/R predictions based on Ot1 in any decision regarding management or exploitation of the stock.

Our predictions of yield per recruit based on Sc1 data were not directly comparable to those predicted by Kock *et al.* from Boronin and Altman's data (fig. 50 in Kock *et al.*, 1985) as the latter were based on a W_∞ calculated from the relationships $W_\infty = 0.0166L_\infty^{2.9}$. However, when their Y/R curves were recalculated using a W_∞ based on the relationship $W_\infty = 0.006L_\infty^{3.1787}$ the predicted yields (at F = 0.5) were 10%-20% less than those which we predicted. Both predictions are based on ages derived from the interpretation of scales alone, and actual measurements of total length. It is reasonable to assume that natural mortality will be little changed since Boronin and Altman's data were collected in 1969-1971. Thus, to explain the above difference, we suggest that growth rate has increased since Boronin and Altman's survey during the early period of exploitation of the South Georgia fish stocks. This is consistent with accepted theories relating to increase in growth rates of newly exploited stocks due to decrease in interspecific competition for resources and supports other analyses of this stock (Anonymous, 1986; 1987b; Kock *et al.*, 1985).

Table I: Estimates of parameters of the Von Bertalanffy growth formula fitted with ages derived from scales (Sc1) and otoliths (Ot1). Standard errors (SE) are given in parentheses.

Age from	L_∞	k	t_0
Sc1	576.9	0.115	-0.534
(SE)	(16.8)	(0.0078)	(0.141)
Ot1	584.5	0.095	-0.812
(SE)	(22.5)	(0.0082)	(0.208)

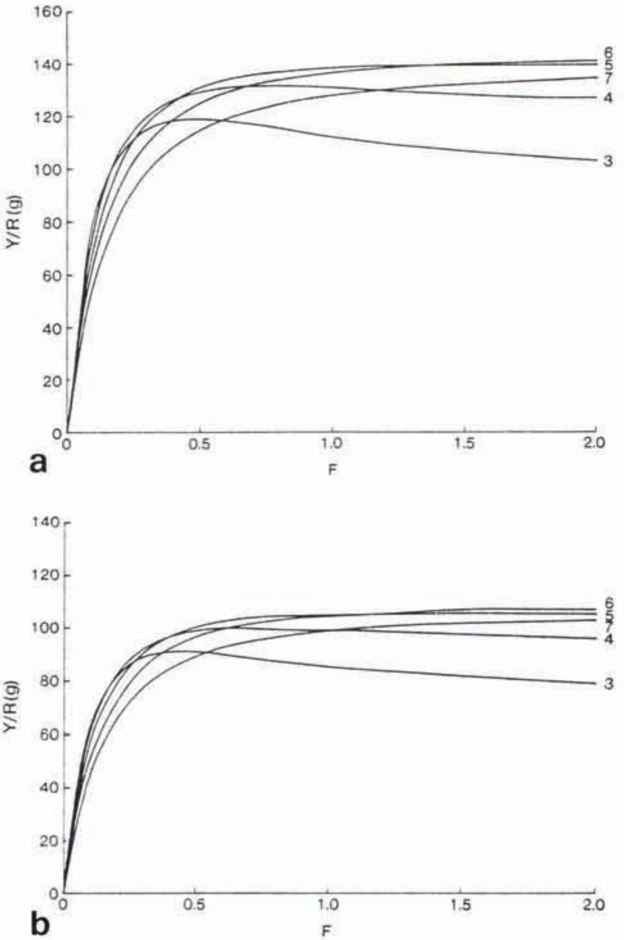

Fig. 7: Predictions of yield per recruit (Y/R) for *Notothenia gibberifrons* around South Georgia plotted against fishing mortality (F) for different values of age (years) at first capture. a: Calculated using growth parameters derived from age interpreted from scales alone (Sc1). b: Calculated using growth parameters derived from age interpreted from otoliths alone (Ot1).

Comparisons with other published work

It is informative to compare a growth curve derived from this study with others for the South Georgia stock derived by Kock *et al.* (1985) from other published data (Table II, Fig. 8). The curve chosen to represent this study is that derived from the joint agreed age (SO) because this is the most reliable length-at-age data available to us.

Hoffman (1982) used pectoral fin-rays for age determination of 186 specimens estimated to be from 4 to 12 years old. The growth curve produced is radically different from those of other studies, indicating either that the age range and size of Hoffman's sample were biased or that there was an unacceptable degree of inaccuracy in that method of age determination. These results must therefore be treated with considerable caution and this method of ageing should not be used until the technique can be shown to produce results which are consistent with other methods.

Table II: Estimates of parameters of the Von Bertalanffy growth formula from recent authors (after Kock *et al.*, 1985) and the joint agreed age (SO) from this study.

Authors	Study period	n	L_∞ (mm)	k	t_0 (yrs)
Shust & Pinskaya (1978)	1969-74	237	585	0.136	-0.09
Boronin & Altman (1979)	1969-71	2328	529	0.15	0.7
Hoffman (1982)	1980	186	474	0.23	-1.35
This study (based on SO)	1986	233	587	0.102	-0.36
(Standard Errors)			(23.2)	(0.009)	(0.190)

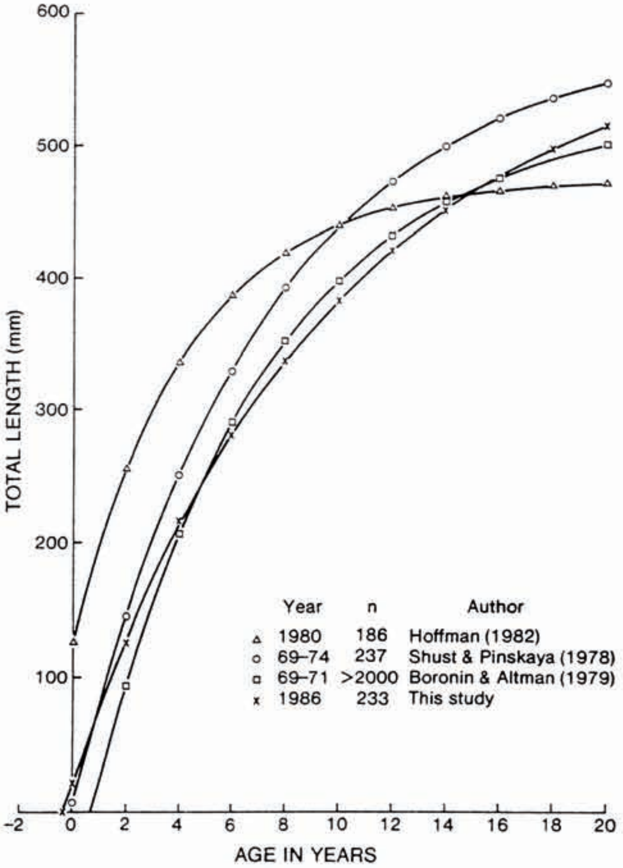

Fig. 8: A comparison of various Von Bertalanffy growth curves for the South Georgia stock of *N. gibberifrons*; as derived by Kock *et al.* (1985) from published data (Hoffman, 1982; Shust and Pinskaya, 1978; Boronin and Altman, 1979) and by this study using age data from the subgroup SO (see text).

Shust and Pinskaya (1978) used scales for age determination of 273 *N. gibberifrons* collected between 1969 and 1974. Mean length at age was obtained by back calculation from scale length assuming a direct proportional relationship. This assumption can not be valid as scales do not record growth during the whole of the life history of the fish. Their methodology, rather than any great variation in the interpretation of scales, is the most likely cause of the differences between their curve and that derived from this study.

Boronin and Frolkina (1976) analysed a sample of more than 2000 *N. gibberifrons* collected between 1969 and 1971. They measured total length (range from 215-491mm) and determined age (range from 3-18 years) from scales. Boronin and Altman (1979) used those data to derive a Von Bertalanffy growth curve which is in close agreement with the curve derived from our study. These curves would therefore seem to be the most applicable to the study and management of this population.

CONCLUSIONS

A number of points of importance to the study of *N. gibberifrons* and its management in the South Georgia fishery have been made and are summarised below.

1. The interpretation of scales is subject to greater variability than that of otoliths. Simultaneous interpretation of scales and otoliths produces least variability.
2. Ages estimated from scales were significantly lower than ages estimated from otoliths. In general, for *N. gibberifrons*, ages determined from scales alone are likely to be one year less than ages determined from otoliths alone.
3. Differences between the ages determined from scales and otoliths are due to differences in the time of formation of the first annulus rather than the rate of formation of successive annuli.
4. The observed differences in age determinations are reflected in predictions of yield per recruit. The use of age data derived from otoliths gave yield predictions which were as much as 30% lower (at $F = 0.5$) than predictions based on less precise age data derived from scales.
5. There is evidence that the growth rate has increased during the period of exploitation.
6. Of the previously published growth curves, that of Boronin and Altman (1979) would have been the most appropriate for use in the assessment and management of this stock.
7. The VBGF recommended for use after this study takes the form
   $$L_t = 587\ (1 - e^{-0.102\,(t - -0.36)})$$
   with the parameters $L_\infty = 587$mm, $k = 0.102$ and $t_0 = -0.36$ years.
8. Further study is required of the 0 and I age groups in order to quantify the difference between the growth recorded by scales and that recorded by otoliths.

Acknowledgements.- We wish to thank those who participated in Phase I of the U.S Antarctic Marine Living Resources Program Ecosystem Monitoring Survey 1986-87 for assistance with the collection of material, Drs Inigo Everson and Eugene Murphy for valuable guidance in the analysis of data and Tony North for comments on the manuscript.

REFERENCES

ANONYMOUS, 1986. - Report of the Fifth Meeting of the Scientific Committee. *SC-CAMLR-V*, 271pp.

ANONYMOUS, 1987a. - U.S. Antarctic Marine Living Resources Program Ecosystem Monitoring Survey 1986-87. Cruise Results. Cruise No. SI 86-01 (I-III). *SC-CAMLR-VI/BG/17*, 6pp.

ANONYMOUS, 1987b. - Report of the Sixth Meeting of the Scientific Committee. *SC-CAMLR-VI*, 236pp.

ANONYMOUS, 1988. - Report of the Seventh Meeting of the Scientific Committee. *SC-CAMLR-VII*, 211pp.

BEDFORD B.C., 1983. - A method for preparing thin sections of large numbers of otoliths embedded in black polyester resin. *J. Conseil*, 41 : 4-12.

BEVERTON R.J.H. & S.J. HOLT, 1957. - On the dynamics of exploited fish populations. *Fish. Invest., Lond.*, Ser. 2, Vol. 19 : 533pp.

BORONIN A.V. & Y.S. ALTMAN, 1979. - Growth and natural mortality of green notothenia. *Trudy Atlant. Nauchno-issled Ryb Khoz. Okeanogr.*, 81 : 66-71.

BORONIN A.V. & Z.A. FROLKINA, 1976. - Age determination of the green notothenia (*Notothenia gibberifrons* Lönnb.) from the S.W. Atlantic. *Trudy Atlant. Nauchno-issled Ryb Khoz. Okeanogr.*, 60 : 29-37.

DEWITT H.H., 1982. - Working party on fish biology. Rep. 2nd Workshop on the Ageing of Antarctic Fishes. BIOMASS Report Series, 26 : 7pp.

EFREMENKO V.N., 1979. - The larvae of six species of the family Nototheniidae from the Scotia Sea. *J. Ichthyol.*, 19(6) : 95-104.

EVERSON I. (ed.), 1980. - Antarctic fish age determination methods. *BIOMASS Handbook*, 8 : 24pp.

FREYTAG G., 1980. - Problems in ageing *Notothenia rossii marmorata*. *Cybium*, 8 : 43-51.

GABRIEL W.L., 1987. - Results of fish stock assessment survey, South Georgia region, Nov.-Dec. 1986. *SC-CAMLR-VI/BG/12 Rev.* 1 : 30pp.

GULLAND J.A., 1969. - Manual of methods for fish stock assessment. Part 1. Fish population analysis. *FAO Manuals Fish. Sc.*, No. 4 : 154pp.

HOFFMAN U., 1982. - Zur Altersbestimmung und zum Wachstum von *Notothenia gibberifrons* Lönnberg bei South Georgia. *Fisch.-Forsch.*, 20(2) : 49-53.

HUREAU J.C., 1970. - Biologie comparée de quelques Poissons antarctiques (Nototheniidae). *Bull. Inst. océanogr. Monaco*, 68 (1391): 244pp.

KOCK K.-H., DUHAMEL G. & J.C. HUREAU, 1985. - Biology and status of exploited antarctic fish stocks. *Biomass Scientific Series*, 6.: 143pp.

NORTH A.W., 1988. - Age of Antarctic Fish: Validation of the timing of annuli formation in otoliths and scales. *Cybium*, 12(2) : 107-114.

PAYNE R W., LANE P.W., AINSLEY A.E., BICKNELL K.E., DIGBY P.G.N., GOWER J.C., HARDING S.A., LEECH P.K., SIMPSON H.R., TODD A.D., VERRIER P.J., WHITE, R.P., TUNNICLIFFE-WILSON G. & L.J. PATERSON, 1987. - Genstat 5 Reference Manual. Oxford University Press : 410pp.

SHUST K.V. & I.A. PINSKAYA, 1978. - Age and rate of growth of six species of notothenid fish (Family Nototheniidae). *J. Ichthyol.*, 18(5) : 743-749.

SKORA K.E., 1980. - Changes in composition of *Notothenia gibberifrons* Lönnberg population of the shelf of South Georgia in the years 1977-1979. *Pol. Polar Res.*, 1(4) : 155-162.

Reçu le 03.03.1989.
Accepté pour publication le 22.11.1989.